Imaging the operation of high explosive detonators

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Exploding foil initiators, also known as slappers or detonators, offer safety and timing advantages over other means of initiating high explosives. However, understanding how detonators perform is challenging. A new capability, developed by researchers from Los Alamos and Lawrence Livermore national laboratories and National Security Technologies, LLC, combines state-of-the-art imaging capabilities with computed tomographic reconstruction in experiments performed at the Argonne National Laboratory's Advanced Photon Source to generate 3-D snapshots of exploding foil initiators. The *Journal of Applied Physics* published the results, which provide the first detailed 3-D images during the operation of the exploding foil initiators.

Significance of the work

Exploding foil initiators consist of a thin conductive foil that is heated and vaporized by a high-voltage, high-amperage electric current. The vaporizing metal accelerates a thin plastic flyer to several km/s across a small (approximately 100 mm) gap. This flyer then strikes and shock initiates an explosive. These initiators offer enhanced safety for two reasons: 1) less-sensitive high explosives are directly initiated, eliminating the need for highly sensitive and more dangerous explosives, and 2) the initiator and associated electrical hazards are not in direct contact with the explosive prior to detonation. Exploding foil initiators also confer precise timing relative to conventional fusing options. In previous exploding foil initiators studies, the small length scales coupled with km/s velocities restricted high fidelity direct experimental measurement of fundamental properties such as the shape of the plastic flyer, nature of the metal plasma, and electrical contact performance.

The new results provide the first detailed flyer structure during the operation of the exploding foil initiator. Flyer shape, curvature, break-up, and elongation have all been measured with ultra-fast x-ray radiographs and the corresponding 3-D reconstruction.

The rich imaging data on EFI and flyer microstructure with time represent a new opportunity to refine the understanding of flyer operation of slapper detonators. Parameters can be tuned to achieve optimal performance. The data will aid in understanding the initiation mechanism for slapper detonators, which is important for assessing aging margins, safety, and performance, and developing new and improved designs for the NNSA Life Extension Programs (LEPs).

This experiment is an example of science on the roadmap to MaRIE (Matter-Radiation Interactions in Extremes), Los Alamos National Laboratory's proposed experimental facility for studying matter-radiation interactions in extremes. Using MaRIE's combination of a unique hard x-ray free electron laser and *in situ* characterization tools, researchers would be able to take this research further with improved time and spatial resolution to capture the early dynamics of these systems, increased x-ray intensities, and higher energies needed to image through complete initiator/detonator systems.

Achievements

The four-camera system from LANL's IMPULSE multi-frame X-ray Phase Contrast Imaging detector system currently located at Argonne National Laboratory's Advanced Photon Source acquired up to eight images from successive x-ray pulses for each shot. The team imaged the exploding foil initiator metal plasma and plastic flyer traveling at 2.5 km/s with 80 ps pulses. The researchers made multiple series of images where the front of the flyer was 0.16 and 0.53 mm above the surface. Multiple acquisitions at different incident angles and the new software package Livermore Tomography Tools produced 3-D images of the flyer. The x-ray images and the 3-D reconstruction both show a strong directionality in the shape of the flyer and underlying foil. These results provide detailed flyer data during the operation of the exploding foil initiator.

The research team

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View a supplemental animation of a 3-D reconstruction and rendering of exploding foil initiator (click on supplemental_efi_animation at bottom of page).